<u>Approach for the Ecological Risk Assessment</u>

Below is direction for conducting key aspects of the Ecological Risk Assessment in Portland Harbor.

<u>Approach for assessing risk from PAHs to resident and anadromous fish</u>
Assessing risk to resident and anadromous fish from PAH exposure in the Portland Harbor is a primary concern of EPA and partners, and literature data indicate that some fish may be more representative of PAH exposure or more sensitive to the effects induced by PAHs than other fish. For example, strong associations between PAH concentrations and measures of exposure and effect have been demonstrated in the literature and include 1) depressed immune system function (immunosuppression), increased susceptibility to disease, and impaired growth in experimentally-exposed juvenile salmonids; 2) increased prevalence of liver lesions, skin lesions, and biomarker responses in brown bullhead exposed to sediment PAHs in the field; and 3) increased liver lesions, hepatic cytochrome P4501A (CYP1A) induction, and xenobiotic-DNA adduct formation in experimentally-exposed flounder and sole. These studies indicate that juvenile salmonids are sensitive to PAH toxicity and resident fish exposed to high concentrations of PAHs from river sediment can be good indicators of exposure and effects. EPA and partners agreed that various lines of evidence need to be incorporated into the Portland Harbor risk assessment to adequately protect fish from PAH exposure, and the modeling approach proposed by the LWG is insufficient by itself and needs to be supported with other lines of evidence.

Currently, to assess risk to fish from PAHs, the LWG proposes to use (1) the dietary approach, using a concentration-based exposure rather than dose-based exposures, and (2) water exposure related only to a single PAH compound compared to Ambient Water Quality Criteria (AWQC). These methods will not be sufficient for assessing PAH risk to fish because (1) there is a paucity of dietary TRVs and the ability to accurately model dietary exposure based solely on concentrations in food items limits the effectiveness of the dietary approach, and (2) PAHs may have a *combined* effect on fish and it is important to consider potential combined effects in assessing risk.

Thus, incorporating some of the possible additional lines of evidence shown below should better address risk to fish (including sturgeon) and meet some of the concerns of EPA and partners. The first three lines of evidence listed below are essential to reduce uncertainty in the LWG's current approach. As soon as possible, EPA and partners will provide additional direction on whether the other lines of evidence listed below will significantly improve the risk assessment and EPA's ability to make cleanup decisions.

- <u>Modify the dietary approach</u>. Express the concentration received by the fish as a dose (e.g., mg chemical/kg fish) rather than solely the concentration in the prey item. There are more reliable TRVs available for comparison when diet is expressed as a dose. Include water concentrations in the model (incorporating water temperature and gill ventilation rates) because a small water concentration of PAHs to fish can result in a huge dose (i.e., uptake efficiency of PAHs can be as high as 50%).
- <u>Chemically analyze stomach contents</u>. Chemical analysis for PAHs in stomach contents of resident fish will better represent what the fish are actually exposed to as compared to only evaluating PAHs in potential prey items. Uptake of PAHs by invertebrates is highly variable and the type of prey evaluated by LWG may not represent what the fish actually eat or the PAHs in the actual prey items. Stomach content analysis will provide a much more realistic exposure scenario and will be used to help verify dietary approach parameters, provide information on the type of prey items the fish consumed that are contaminated (important for the food web model), and better represent the specific types of PAHs the fish was exposed to (needed for attributing PAH groupings to sources). Concentrations in stomach contents can also be compared to concentrations in fish from other sites where effects from PAH exposure have been observed. Analysis of stomach contents is critical if resident fish are to be used as a representative for sturgeon, and should be conducted on any sturgeon collected from the site.
- <u>Analyze biliary FACs (fluorescent aromatic compounds)</u>. Analysis of biliary FACs in resident fish will help better identify exposure to PAHs and indicate what types of PAHs the fish has actually metabolized

(i.e., urban type, petroleum type, etc.). FACs are expressed as PAH-equivalents, but additional analysis of bile material could be done to identify individual metabolites. This biomarker (i.e., a measure of a biological or physiological response an organism has when exposed to a stressor) has been correlated with other measures of effect in fish exposed to PAHs in other studies, and can be used as an inexpensive monitoring tool to measure reduction in exposure resulting from remedial actions.

- Evaluate growth endpoints is juvenile salmon. Recent data from the NOAA Science Center indicates that measurements of growth and metabolic alterations in juveniles correlate with PAH exposure.
- Measure immunocompetence in juvenile salmonids. Immunocompetence (susceptibility to disease from PAH exposure) has been well documented in juvenile Chinook salmon, and experimentally-controlled exposure challenge studies can be useful in determining if juvenile salmon in Portland Harbor have PAH-related disease susceptibilities that threaten their survival.
- Sediment thresholds derived by the NOAA Science Center. These thresholds will be helpful for linking the incidence of fish lesions with sediment concentrations (i.e., run bioassays in high PAH areas and use existing sediment data and sediment quality guidelines to help predict if and where lesions would be expected).
- Evaluate DNA adducts. Strong associations have been documented between PAH-specific DNA adduct formation and hepatic cytochrome P4501A (CYP1A) induction, bile FACs, and liver lesions for resident-type fish. Contaminant specific DNA errors can be traced back to specific PAHs.
- Experimental exposure to PAHs. Conduct toxicity testing for fish and invertebrates.
- Use invertebrate surrogate toxicity. Using invertebrate surrogate toxicity could help be helpful to protect fish from PAHs (note: this would help bridge the large data gap related to the invertebrate-PAH link).
- Develop species sensitivity distributions. A species sensitivity distribution could be developed to create sediment guidelines.
- Water concentration approach. Compare water column PAH data to pseudo screening numbers in the EPA sediment equilibrium partitioning guidance document.
- "Sum PAH" test. This test was developed in Newport, OR for assessment of amphipods and other species.

In addition to fish, PAH risk to the benthic and epibenthic community (i.e., clams) should be assessed, but this does not appear to be a data gap at this point.

Approach for assessing risk from PAHs to birds and mammals

Because many PAHs are metabolized in fish and do not readily transfer up the food chain, exposure to higher trophic level receptors such as birds and mammals from ingesting contaminated prey is difficult to measure and considered complete and insignificant in most cases. However, ingestion of PAHs for birds lower in the food chain such as sandpipers and mergansers should be modeled through a dietary approach if appropriate TRVs are available. A primary concern for birds and mammals is dermal exposure to PAHs. These animals are very susceptible to hypothermia and death when dermally exposed to petroleum compounds such as spills, sheens and tar-oil bodies. However, dermal exposures are difficult to assess or predict in a risk assessment and are typically covered in other laws and regulations. EPA and partners would like the LWG to explore whether methods exist for dermal exposure scenarios (these may be more important at site-specific locations).

Approach for assessing risk from metals to fish

Currently, to assess risk to fish from metals, the LWG proposes to use (1) the dietary approach and (2) comparisons of dissolved metal concentrations to Ambient Water Quality Criteria (AWQC), with the assumption that AWQC will be protective of all fish. These methods are not adequate for assessing risk to fish from metals exposure because our understanding of gill uptake efficiencies and ventilation rates resulting in toxicity are somewhat limited. To help resolve this data gap, LWG should analyze metals in fish stomach content (see the additional line of evidence noted above under *Approach for assessing risk from PAHs to resident and anadromous fish*) which will help reduce uncertainty in the dietary approach for assessing risk to fish from metals. Other options to improve the assessment include using biomarkers such as metallothionene and using the Biotic Ligand model that EPA is developing.

In order to reduce uncertainty in assessing risk to fish from metals without losing focus on the more prevalent contaminants (PAHs and PCBs), we will (1) rely on toxicity to the benthic community to assess metals risk as opposed to tissue residue levels (tissue residue levels for metals are less reliable because fish regulate metals), (2) look at fish-specific water TRVs, which are more reliable and cost-effective than doing biomarker-specific metals evaluations for fish, and (3) refine the dietary approach for metals using data collected from fish stomach contents analysis.

Approach for assessing risk from metals to other receptors (inverts, clams, birds, etc.)
The TRV/direct toxicity assessment is sufficient for assessing risk to clams and invertebrates. For birds, the proposed dietary approach for assessing metals risk is sufficient, with the possible exception of getting verifiable tissue data. Options for getting bird tissue data include evaluating prey items fed to nestlings using a dietary ligature approach. This approach would allow for identification and chemical analysis of prey items and can be used to assess metals risk as well as other contaminants, and this approach may be most needed at specific site locations. Swallows are commonly used to assess risk at PCB sites based on dietary ligature information as well as assessing reproductive endpoints.

Approach for assessing risk from specific organometals to fish
Currently, to assess risk to fish from specific organometals (TBT and other butyltins), the LWG proposes to use (1) TBT risk to clams and mussels, and (2) a TBT sediment number protective of salmonids feeding on invertebrates. TBT is highly toxic to gastropods and is bioaccumulative in invertebrates. We suspect, however that there are no native gastropods in the Portland Harbor area that we need to specifically protect, and therefore risk assessment would be focused on protection of invertebrates in the Harbor and the consumers of exotic gastropods or related organisms. The current LWG approach appears sufficient unless additional information is obtained that indicates native gastropods are using Portland Harbor or should be in the Harbor. In addition, the LWG also needs to assess risk to fish (including prey items) using the Meader paper[1], and a localized TBT risk assessment will be needed for TBT contaminated sites.[2]

Approach for assessing risk from mercury to fish and invertebrates
For assessing risk to fish and invertebrates from mercury, the LWG proposes to use (1) the benthic interpretive model and (2) the tissue residue approach. These approaches are adequate.

Approach for assessing risk from mercury to amphibians, birds and mammals
For assessing risk to amphibians, birds and mammals from mercury, the LWG proposes to use (1) the dietary approach and (2) evaluating the accumulation of mercury up through the food chain to birds. This approach is adequate, but we may need to review the TRVs to ensure they're appropriate and protective enough.

Approach for assessing risk to sturgeon, Chinook and lamprey
The LWG's proposed Assessment Endpoint Table and the Ecological CSM identify sturgeon, juvenile lamprey and juvenile Chinook as receptors of concern. EPA and partners added *adult* lamprey and *adult* Chinook as receptors of concern because complete pathways exist to these receptors that are not represented

[1] Meador, J.P. 2000. An analysis in support of a sediment quality threshold for tributyltin to species for juvenile salmonids listed by the Endangered Species Act. Final Report. Northwest Fisheries Science Center, NOAA, Seattle, WA. 19 p

[2] Note: The Meader paper may not be protective of gastropods or mollusks. For gastropods, we are not interested in protecting them as endpoints themselves, but we are interested in gastropod bioaccumulation and how this affects birds. We do want to protect mollusks as endpoints, however, and we could use a TRV approach for assessing risk from TBT and compare this to the Meader paper's recommendation of a sediment cleanup level that is ten or more times lower than 6,000 ng/g organic carbon.

by other species or by the juveniles, and because the adults are culturally significant to the Tribes. EPA is considering whether sturgeon and lamprey will be assessed and protected at an *individual* level, rather than at a population level, to reflect the special status of these species to the Tribes and because some data indicate that these species have declined in much of their range.

Assessing sturgeon

Currently, the LWG proposes to assess risk to resident omnivorous/herbivorous fish, including sturgeon, by assessing and protecting resident species such as largescale sucker and pikeminnow as sturgeon representatives. In order to best ensure protection of sturgeon, EPA and partners agree that sturgeon should be evaluated independently of other resident fish for the following reasons:

- insufficient data exist regarding levels of contaminants in prebreeding sturgeon, and no data exist regarding levels of contamination in adult sturgeon in the ISA;
- sturgeon are unique in their life history and physiology (being evolutionarily very distant from all other fish species in the ISA);
- sturgeon can live to at least 100 years of age and therefore have a much longer time to be exposed to and accumulate persistent contaminants compared to shorter-lived resident species;
- no TRVs are available for either prebreeding or adult sturgeon, and therefore direct comparisons of contaminant sensitivities between sturgeon and resident fish are not possible and would be inappropriate without employing possibly overprotective uncertainty factors;
- data from laboratory-exposure studies would be helpful in gaining a better understanding of the relative sensitivity of prebreeding sturgeon compared to other species; and
- since sturgeon are long-lived, development of TRVs for adult sturgeon is technically challenging.

Resident fish, such as the largescale sucker, have a much different dietary pathway than sturgeon and other parameters will be needed to model the dietary pathway for contaminant exposure in sturgeon. EPA and partners agree that since sturgeon consume prey in Portland Harbor, the dietary pathway for sub-adults and adults is complete and significant, but it will be difficult to determine the relative contribution of contaminants to sturgeon from areas within and outside of Portland Harbor.

The approach proposed by the LWG for assessing risk to sturgeon is not adequate alone, and needs to be supplemented as follows. EPA and partners agree that largescale sucker and pikeminnow can be used in preliminary food web analyses as the representative of all species, including sturgeon, in the "omnivore/herbivore" guild to estimate tissue concentrations in prebreeding and adult sturgeon. However, for the reasons presented above, protection of these surrogate species may not adequately protect sturgeon, and relying on uncertainty factors alone to fill data gaps rather than more specific sensitivity information might be unrealistic. Collection of sturgeon within the ISA in the size range believed to represent more resident prebreeding individuals is necessary. Concentrations of analytes obtained from empirical tissue analyses from these individuals can then be compared to (1) levels in composite tissue samples of other fish receptors, and (2) estimated tissue levels for other fish species (methods yet to be determined) to assess whether protection of other fish species will also be protective of sturgeon. In addition, contaminants in adult sturgeon must be estimated based on a model using empirical data from prebreeding sturgeon that incorporates the potential for greater bioaccumulation in the longer-lived adults. As with prebreeding sturgeon data, these estimates of adult tissue contaminant concentrations must also be compared to levels in composite tissue samples of other fish receptors and estimated tissue levels for other fish species.

Because the model must assume 100% site use and consider longevity (up to 100 years) in the ISA, this is likely to result in risk levels that are beyond maximum clean-up levels. If EPA and the LWG believe that such results are overly conservative and want to change risk estimates by reducing the adult residency assumption to less than 100%, additional empirical data would be needed to support such a change. If appropriate empirical data already exist, EPA and partners can evaluate these data and determine whether they are sufficient or whether additional data collection from the ISA is needed. Alternatively, the LWG may choose to begin gathering ISA specific data on adult sturgeon residency before the above analyses are complete, because one to three years of data collection will be required to gain useful information.

Assessing Chinook

Although adult Chinook take up contaminants during migration through the ISA, protecting juvenile Chinook as an assessment endpoint was expected to provide protection for all live stages. Protection of juvenile Chinook does not, however, take into account the effect of contaminants on returning, pre-spawning adults that may suffer impaired olfactory function from copper and other metals. Impaired olfactory function affects the ability of adults to find spawning sites and effectively reproduce. EPA and partners agree that surface water metal concentrations should be compared to known effect levels for adult olfactory function to assess risk to adult Chinook. In addition, TRVs should be used to evaluate physiological and other effects on adults.

The dietary pathway for bioaccumulative contaminants for adults is considered to be insignificant. This pathway is significant primarily to yearlings and sub-yearlings that are eating invertebrates during their time in the ISA.

The Assessment Endpoint Table needs to be modified to specify "Chinook" as an endpoint, with two subsequent categories for "juveniles" and "adults." For assessing "adults," the table should note that adults will be assessed only for olfactory function of returning, pre-spawning adults, tied to water column contaminant concentrations, and how changes to olfactory function may affect swimming, homing behavior and ultimately reproduction. Adding adult Chinook as an assessment endpoint for this contaminant-receptor interaction is important because it represents a unique exposure-receptor pathway, and it is tied directly to salmon survival and reproduction.

The process for assessing risk to juvenile Chinook should include collecting data on juvenile Chinook tissue and diet, and using peamouth as a surrogate. Peamouth should provide conservative risk estimates because it is a resident species, but the juvenile Chinook and peamouth diets differ enough to warrant using a dietary model to estimate risk to juvenile Chinook based on their actual diet (which primarily includes daphnia based on existing studies).

Assessing lamprey

EPA and partners are still evaluating potential approaches for assessing lamprey in the ERA. Direction from EPA and partners to the LWG on lamprey assessment will be provided soon.

Approach for developing BSAFs for clams, crayfish and sculpin

BSAFs for clams, crayfish and sculpin are needed to describe the relationship between contaminant concentrations in tissue and sediment in the ISA. In addition, if a sufficiently robust relationship can be developed, BSAFs will assist with estimating tissue concentrations in areas in which receptor tissue samples were not collected, developing clean up levels for bioaccumulative contaminants, and informing the ERA Dietary Approach and Food Web Model. BSAFs can be used on a Harbor-wide basis and developed for specific sites to represent localized sediment-tissue contaminant concentration relationships. Data analysis will tell us whether we have a strong sediment-tissue relationship Harbor-wide, and data outliers could indicate areas where additional site-specific BSAFs should be developed for local areas (additional sampling may be needed in these areas). We also will consider possibly developing BSAFs for lamprey ammocoetes and sucker.

The current approach for developing BSAFs is to use field-collected clams and do lab tests with clams and *Lumbriculus*. EPA and partners will need to evaluate the data generated from this effort to determine whether the various sediment-tissue relationships are strong enough, and to decide whether additional sampling is needed. In addition, we need to evaluate the existing crayfish-sediment data and sculpin-sediment data to determine the strength/quality of the tissue-sediment relationships. Additional data collection may be needed to improve the sculpin-sediment contaminant concentration relationship and provide additional information to explain some of the outliers

Approach for assessing risk to the benthic community
The proposed approach for assessing risk to the benthic community includes (1) laboratory toxicity tests as the primary line of evidence (an empirical and predictive approach), and (2) comparing tissue concentrations from field collected clams and crayfish to tissue based TRVs. This approach is not adequate because (1) lab toxicity tests are spatially limited, and (2) field collected tissue is spatially limited and informative for only two species that may not adequately represent other benthic organisms. In addition, this approach is missing analyses of the benthic infaunal community.

In addition to the proposed approach, the LWG needs to use Equilibrium Partitioning (EQP), which takes into account bioavailability. Empirically-obtained or estimates of porewater concentrations, along with acid volatile sulfides and simultaneously extracted metals data, are needed to help interpret results of bioassay toxicity testing and to provide greater certainty for assessing risk to the benthic community.

Approach for assessing risk in the riparian area
A portion of the lower riparian area within the ISA provides important habitat for receptors of concern, and as such, it must be considered in the ERA. EPA and partners defined the lower riparian area as river bank that extends up to the Ordinary High Water Mark[3] (OHWM), and agreed that the Portland Harbor Remedial Investigation must include assessment of this area. Some upland Responsible Parties are responsible for assessing the upland area down to the Mean High Water Mark, but these assessments are done relative to discrete sources, rather than being designed to assess continuous risk to aquatic receptors in the ISA. Assessment of the lower riparian area by the LWG is important to provide consistency in the assessment and in protection of the species that use the area throughout the ISA.

Scale of the ERA
The LWG has proposed developing Harbor-wide cleanup levels during the RI/FS, and developing more specific cleanup numbers in the RDRA phase. EPA and partners agree that looking at site wide cleanup levels is acceptable for now, but additional cleanup levels may be needed for localized contaminant areas before completion of the RI/FS, and additional data collection may be required. EPA and partners are concerned that risk information was not collected to support the Early Actions (T4 and Gasco), and that site specific risk assessments will be conducted during the RI/FS when needed. From this point forward, EPA and partners will direct the LWG to conduct more sampling and analysis than the minimum level needed to assess Harbor-wide risk or develop Harbor-wide cleanup levels because we are interested in localized risk in some areas.

Weighting different lines of evidence for the ERA
In the near future, EPA and partners will provide develop an approach for weighting different lines of evidence for different contaminant families (metals, PAHs, PCBs, other organics, etc.). A weighting approach will be needed to focus the risk assessment (beyond the screening level) on those exposure pathways that are most important for driving risk to different receptors. EPA and partners will provide direction on the weighting approach to the LWG when it is available.

[3] The OHWM is the transition from a more aquatic system to a terrestrial system, usually visible by the vegetation line on the shore.